2

RELATIVE *f*-VALUES OF POTASSIUM ATOM

By JATINDER NATH NANDA

(Plate I)

ABSTRACT Principal series lines of potassium have been studied in absorption. Construction details for the high intensity hydrogen discharge tube as a source for ultraviolet light, and a sensitive intensity reducing device are given. On account of uncertainty in the number of absorbing atoms due to the presence of foreign gas and cold ends in the absorption tube, relative *f*-values alone have been worked out.

f-value of the first line relative to the second varies with the conditions of experiment from 16.1 to 6.4; the theoretical value is 91.5 and experimental value from anomalous dispersion Hook method is 98.5. Extremely low values obtained from the present direct method need clarification. On the photographic plates, in addition to the atomic lines, strong molecular bands also appear, though the expected number of K_2 molecules is only 3 to 4% of the total vapour present.

There is no sudden drop of intensity from the fourth to fifth lines as given by theory. However the intensity does not decline smoothly with the series number. Some lines show slightly greater intensity than the preceding ones (*e.g.*, 10th and 13th). The continuum at the head of the series limit shows a broad minimum at about 2700 Å, the absorption increasing towards shorter wave lengths. This anomaly has also been reported by others.

1 INTRODUCTORY

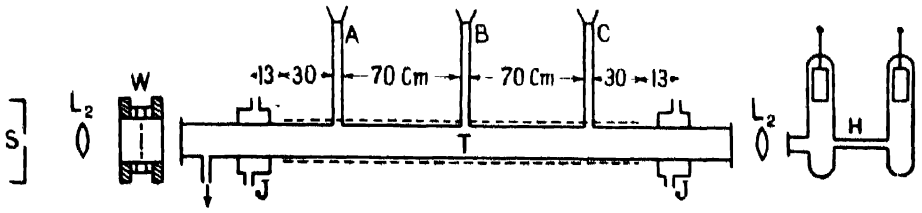
The study of intensity of spectral lines have assumed great importance due to astrophysical and theoretical significance. Absorption spectra are preferred on account of comparative ease in controlling the conditions for obtaining these. Alkali aborption spectra have received considerable attention on account of their simple structure. Various methods have been developed to measure the line intensities (Mitchell and Zemansky, 1934).

Besides other methods the direct method, that of measuring the area under the graph for absorption coefficient with frequency, has been employed by Trumpy (1925, 1927) for evaluating relative *f*-values of lithium and sodium. A modification of the method, employing the area under the absorption contour itself (Total absorption method) has been extensively used by King and others (1940) for *f*-values of copper, etc. Continuous absorption at the head of principal series has been studied by the direct method for lithium, sodium, potassium and caesium by various authors, *e.g.*, Trumpy, Bott, Ditchburn and co-workers.

For the last few years experiments on absorption spectra of potassium under varying conditions of temperature and foreign gas pressure have been conducted in this laboratory. Potassium was selected since its line absorption has not been studied by absorption methods. The results and the methods employed are given as follows :

2 ABSORPTION TECHNIQUE

The experimental set up for observing photographically the absorption of an alkali vapour consists of the following four parts (Fig. 1).



Experimental Arrangement

FIG. 1

(*i*) The source for continuous background (H).

(*ii*) The absorption tube (T) where the alkali metal is vaporized.

(*iii*) An intensity reducing device (W) to calibrate the photographic plates.

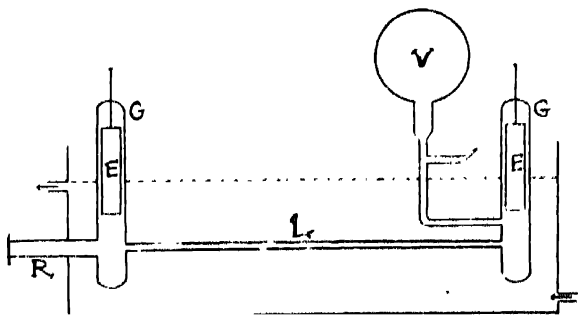
(*iv*) The spectrograph (S)

A brief description of each is given below :—

(*i*) The background source.—The principal series of potassium extends from infra-red to near ultraviolet, the resonance line having a wavelength about 7700 Å and the limit being at 2850 Å. For the first and the second member (4046 Å) a straight filament tungsten in glass lamp (10 Volts 5 Amps.) was used as the source. It was fed by a transformer from A.C. mains. The current was seen to remain constant in any exposure. The photographs were taken on Kodak infra-red plates.

For the region of second line onwards a high power water-cooled hydrogen discharge tube gave an intense ultraviolet background illumination. The photographs were obtained on Ilford process plates. The tube was constructed especially for the purpose. We may here mention briefly its method of preparation since the tube is practically indispensable for ultraviolet quantitative photometry. It possesses all the prerequisites of such a source namely, intensity, steadiness, and almost continuous spectral distribution of intensity.

The discharge tube was entirely made of pyrex excepting the quartz window which was wax-jointed at one end. The conditions of discharge in a similar tube have been studied by Bay and Steiner (1927). For special requirements the intricate designs suggested by Lawrence and Eldefassen (1930) and Kistiakowsky (1931) may be followed. The discharge tube, employed in these experiments is shown in Fig. 2. It consists of a long tube L (50 cms. long and 5 mms. bore) connecting two upright tubes G (20 cms. long, 3 cms. wide) in which hollow cylindrical aluminium electrodes (E) are sealed by tungsten pyrex seals.



Hydrogen Discharge Tube

FIG. 2

The electrodes do not touch the glass walls, being of slightly (2 mms.) less diameter than the tubes G. One of the side tubes is connected to a large flask (2 litres capacity) which does not allow changes in pressure due to discharge. The tube is to be viewed end on for getting large intensity. A side tube R (12 cms. long 2 cms. wide) carrying the quartz window at one end is sealed on to one of the side tubes exactly in line with the discharge tube. The whole tube dips up to the middle of the electrodes in water renewed continously in a galvanized iron tank. The tube R projects out of an opening in one of the side walls of the tank. The tube is held in position by a strong wooden frame supported on four legs fixed on the support of the tank. In this position the tube has stood for months without giving the least trouble.

Pure and dry hydrogen is introduced by the side capillary C which is later sealed off at the required pressure (about 1 mm.) inside the tube. Hydrogen was prepared by electrolysis over nickel electrodes, of barium hydroxide solution in distilled water. The gas entered the tube through a calcium chloride tower and a liquid air trap in succession. The collecting tube could be isolated by a vacuum stopcock. The whole apparatus could be evacuated to very low pressures by a mercury diffusion pump, the pressure being read on a McLeod gauge. First the apparatus was rinsed with hydrogen by repeated fillings and evacuations. Later it was exhausted continuously while individual parts of the tube were gently heated by flame to remove any loose traces of gas. Finally after it had been again alternately filled with hydrogen and exhausted, the stopcocks were closed when the pressure inside was 1 mm. On observing the discharge, first various bands appear on the plate, but when purifying action of the discharge has continued for some time (about ten hours) the spectrum consisted of a beautiful continuum practically free from any structure. The tube was then sealed off. The tube gives very intense light and consumes more than a thousand watts at 3000 volts.

Due to the length of the tube, the collimating lens must be of large focal length so that it has a greater depth of focus. A quartz lens L_1 of 86 cms. focal length was placed at distance of 50 cm. from the end of tube. The parallel beam of light passed through the quartz windows enclosing the absorption tube, and converged through a lens L_2 of 50 cm. focal length on to the slit of the spectrograph. The focal length of this lens was large so that the light image on the slit is of some size. The optical system is clear from Fig. 1.

(*ii*) The absorption tube T was of three meters length and 2.5 cm. internal diameter. It was constructed by end to end welding of short lengths of thin steel tubing. The ends were closed by pyrex glass caps carrying annular discs of brass with groves to support plane quartz windows of 1 cm. free aperture. All the joints at the ends were made by sealing wax. Three iron tubes A, B, C each 30 cms. long and having one cm. bore were welded to the main tube at regular intervals. Alkali metal could be introduced directly into the absorption tube through these side tubes in the beginning of the experiment. Later pyrex glass tubes carrying iron-constantan thermocouples were introduced in each of

the tubes. In the working position the side tubes were kept inclined to the vertical so that the ends were not heated up by the heat from the heating coils on the main tube ; and the thermocouple tubes could be held in position by rubber corks and plasticene. The hot junction of the thermocouples was kept well into the main tube, the cold junction was kept at room temperature and the temperature differences were read on a Crompton potentiometer.

Since the glass or quartz windows are attacked rapidly by the alkali vapour, the ends of the tube had to be kept cold by circulating water in the end jackets J. A side tube F connected the absorption tube through a short length of rubber tubing to various gas reservoirs (He, A, N_2), a McLeod gauge, a mercury manometer, and the evacuation pump. The whole assembly must be leak tight.

The greater part of the length of the absorption tube could be heated by a heating coil of nichrome wire (divided into 8 segments in parallels drawing up to 20 amps. in all) insulated from the tube by asbestos sheet and heavily lagged by asbestos rope. The temperature could be fairly kept constant by altering the resistance in series with the heating coils.

(*iii*) Since the intensity of the source varies over the photographed region and the photographic plate has different response at different wavelengths, a simple relation between the intensity and the ensuing blackening cannot be employed everywhere. It is therefore necessary to use some calibration marks on the plate. Intensity is reduced in a known ratio and a calibration exposure is obtained, keeping the time of exposure same as that used for absorption or background exposures. Out of various intensity reducing devices, the wire screen type has been selected on account of its simplicity and greater sensitivity. Ditchburn's (1927) rotating sector device has not been used since it cuts off the available intensity to one half.

A screen is formed by stretching a number of metallic strips of uniform width on a wooden ring. From the mean diameter of the strips and their total length inside the ring, the area obstructed by the screen is calculated. Each of such screens thus transmits a certain percentage of light falling on it.

The ring supporting the screen is fitted in the wooden tube capable of rotation in ball bearings at the ends. The tube is rotated by a low power motor. The screens are to be rotated to produce randomness of the transmitted pattern on the collimating lens of the spectrograph. It also averages out any radial variation in the beam of light. The screen is placed in the optical path near the absorption tube within the focal distance of the condensing lens. Many calibration spectra can be obtained by crossing any two of such screens. To avoid diffraction effects the breadth of the wires or the openings should not be less than 1 mm.

Sensitivity (S) may be defined for such a device by

$$\frac{1}{S} \quad \frac{1}{I} \cdot \frac{dI}{dN}$$

where I is the transmitted intensity and N the number of equidistant wires of breadth a in a square mesh (for simplicity) of length L.

$$\therefore \frac{1}{S}=\frac{I}{I_0}\cdot\frac{a}{L} \text{ or } S=I_0\frac{L}{a}.$$

If $I_0=1$ cm, $a=1$ mm. then $S=10I$ which is larger than that for any other device. A possible drawback in the device is that the calibration points are fixed, whereas in other devices the transmitted intensity can be altered to suit the exposure under investigation. But in study of line absorption this is not important due to wide variations in any line.

Actually four such meshes were constructed and by combining some in pairs, in all seven distinct calibration spectra could be taken corresponding to following transmissions 23.0, 53.5, 76.5, 85.5, 65.4, 40.9, 26.5.

(*iv*) A Hilger medium size E 2 quartz spectrograph was used. It has a dispersion of about 12 Å in the uitraviolet and about 100 Å in the near infra-red region. Due to relatively low dispersion of the instrument only first two of the potassium doubles could show a measurable separation of the components and that too only under conditions of low temperature and low foreign gas pressure. But since the intensities were to be compared for the doubtlets as a whole a larger dispersion was not considered necessary.

Slit width was kept at 3 μ and it was verified, now and then by measurement with a high power microscope, to remain canstant. Since special thin plates could not be had, the curvature inside the plate-holder was slightly reduced so that $4''\times10''$ plates, cut out of commercial $10''\times12''$ plates on fitting in the holder, do not break by the pressure of the springs.

3. EXPERIMENTAL PROCEDURE

(*a*) *Manipulation of the metal*—

Outer layers of the oxide on the metal balls are scraped off under kerosene oil and the metal is cut into thin pieces. It is then put into the sides tubes after removing the oil by dipping the pieces in ether. The pieces of metal are dispersed in the absorption tube by shaking them with long iron needles which can be introduced through the side tubes. To avoid oxidation, the whole operation must be carried out quickly. As soon as the required quantity of potassium has been put the thermocouples are introduced and fixed in position. The closed side tubes are now tilted to the vertical, and the absorption tube is evacuated by an oil pump. Then a few mms. pressure of foreign gas is introduced to safeguard against rapid distillation of the metal to cooler parts on heating The extra purification of the metal has been found to be not necessary.

(*b*) *Order of exposures*—

A background exposure through the cold absorption tube and with no calibration screen in the path is now taken. The tube is heated by the heating

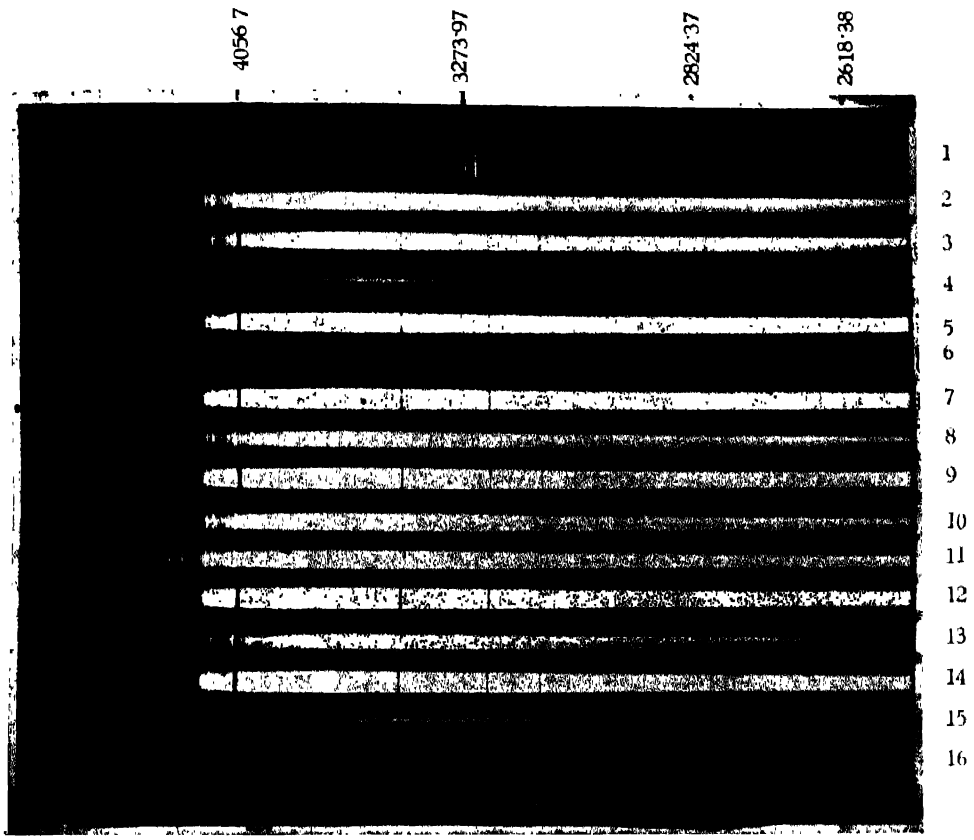


Fig. 1
An Absorption Photograph
Exposure Nos. 2, 11 :—Background exposures
Exposure Nos. 3, 5, 7, 9, 12, 14 :—Absorption under foreign gas pressures ·7, 1·3, 2·7, 5·4, 8·0, 10·5 cms
Exposure Nos. 4, 6, 8, 10, 13, 15, 16 :—Calibration spectra
Exposure No. 1 :—Copper line spectrum for reference

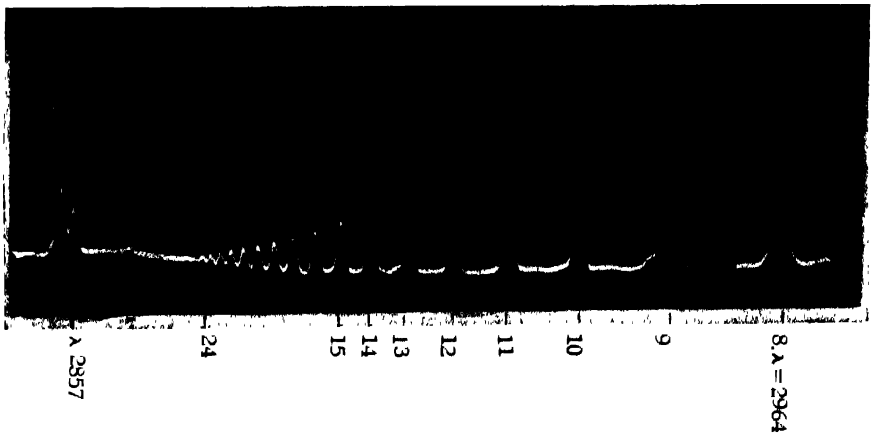


Fig. 2. Microphotogram of Exposure No. 12, Table I
Series lines 8-24.
Doublet near limit 2857 is due to Sodium impurity

coil. After waiting for at least half an hour, so that steady conditions have been reached, the first absorption exposure is obtained. Few more such exposures with varying conditions of temperature or foreign gas pressure (one remaining constant) are also taken on the same plate. Sufficient time is allowed between two exposures. The current in the heating coils and the current in the primary of the transformer feeding the hydrogen discharge tube is kept constant by hand control during any exposure. Exposure time was kept at 10 minutes for the process plates and 5 minutes for the infra-red plates. Three observations of temperature difference for each of the three thermocuples A, B and C. Room temperature and pressure were noted during each exposure. The tube is now allowed to cool and a background exposure and the calibration exposures are obtained. A reference line spectrum of copper for the ultraviolet and of neon for the infra-red region is taken on each plate. Any plate thus contained three or four absorption spectra, two background spectra, and six or seven intensity calibration spectra besides the reference spectrum (Plate 1 A).

(c) *Developing the plates*—

Care is taken to develop the plates evenly. The plate is put in developing solution in such a way that points along any line parallel to the breadth are immersed at the same time. The dishes are rocked gently. After developing and fixing, the plates are thoroughly washed in running water for several minutes. The plates are then quickly dried in a horizontal position under a fan.

(d) *Microphotometry of the plates*—

Plates were microphotometered on a Siegbahn photo-voltaic type microphotometer with wedge coupling. Magnification ratios 7, 15, 20 were used. Higher ratios were not used due to very slow speed of the work on account of lack of a string instrument. Only those lines were selected for microphotometry which did not show completely absorbed centres because the direct method is applicable only to such lines. After getting the microphotogram for the absorption line, the deflections corresponding to calibration exposures at intervals of about 200 Å were recorded. Microphotometer readings for continuous absorption beyond the series limit, some of the calibration deflections, and clear plate readings were taken visually.

(e) *Reading the microphotograms*—

Average of clear plate readings, if they do not show any marked changes, is subtracted from all microphotograph readings. To read the microphotogram accurately, it is mounted in a vertical plane between two glass plates. The readings are taken by a travelling microscope capable of moving in a horizontal as well as a vertical direction. Thus ordinates to correspond to photometer deflections are read against the distance along wavelength scale. Those points are especially read where the absorption contour shows a peak or leaves the base lines or is cut by calibration deflections.

4. METHOD OF CALCULATION

The microphotogram trace for the densest exposure (due to background) corresponds to 100% transmission. The ordinate corresponding to it from the clear plate deflection as zero is noted. Similarly ordinates for other calibration spectra for any wave length region are noted. A graph is drawn between these magnitudes and the percentage transmission. The transmission can then be read off for any point on the absorption contour (Fig. 3).

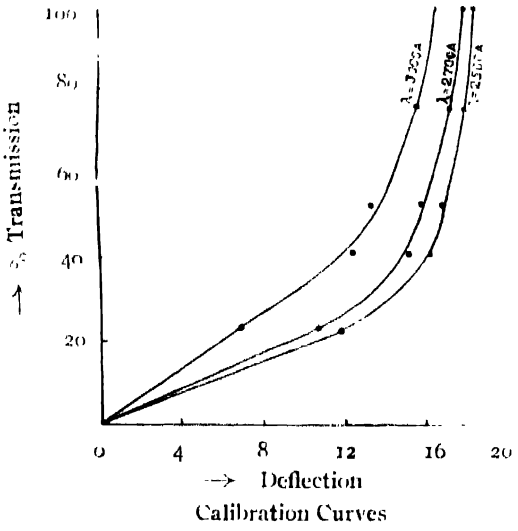


FIG. 3

Let T_ν be the % transmission at any ν, then

$$T_\nu/100 = e^{-lk_\nu}$$

where k_ν is the absorption coefficient at ν (wave numbers) and l is the length of the absorbing vapour. k_ν evidently $\propto (2-\log_{10}T_\nu)$. Thus for any line the area G under the graph $(2-\log_{10}T)$ against ν is proportional to integrated absorption $\int k_\nu d\nu$. And since $\int k_\nu d\nu \propto Nf$, the area G is a measure of f-values of lines in the same absorption spectrum. Actually the graph was not drawn for ν but for distance x along the records, so G was obtained by multiplying the area under the actual graph by $\frac{d\nu}{dx}$ at the position of the line.

For calculation of absolute f-values we know that

$$\int k_\nu d\nu = \frac{1}{l}\{\int \log_e 10 (2-\log_{10}T_x)dx\}\cdot\frac{d\nu}{dx} = \frac{G}{l}\log_e 10$$

and also

$$\int k_\nu d_\nu = \frac{\pi e^2}{mc} Nf$$

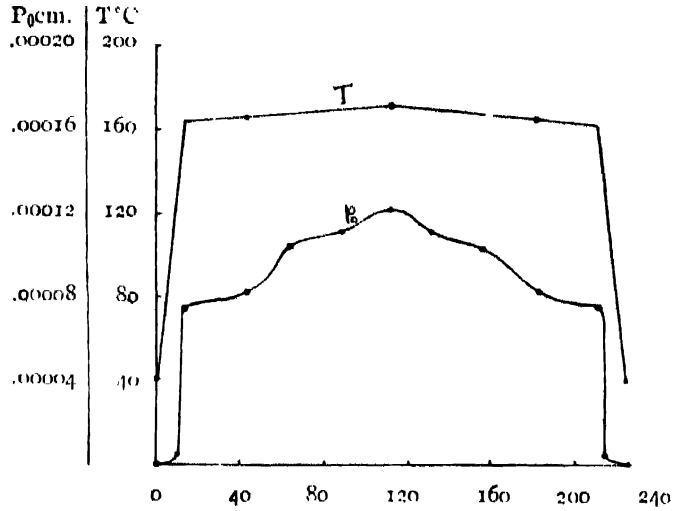
where N is the number of absorbing atoms per c.c.

$$\therefore f = \frac{mc^2 G \log_e 10}{Nl\pi e^2}$$

N is obtained from the vapour pressure data as follows:

If p is the vapour pressure at T° C then $p_0 = p\cdot\frac{273}{273+T}$ is the reduced pressure and $N = N_0 p_0$ where N_0 is the Avogadro number reduced to one c.c. and 1 cm. pressure, *i.e.*, $N_0 = \frac{A}{22{,}400\times 76}$. However, since the temperature is

not constant along the length of the tube, a simple mean of either temperatures or of vapour pressure is not reliable. Assuming thermodynamic equilibrium a better approximation is to plot the vapour pressure p from known temperature data along the length of the tube, and to reduce the resulting curve to 0°C on the same graph. The area of this curve now gives the product $p_0 \times l$ to be used in the formula (Fig. 4). But due to the presence of cold spots on the tube and due to the disturbing effect of the foreign gas, actual vapour pressure can not be assumed to be given by the vapour pressures at those temperatures. Hence absolute f-values from this arrangement cannot be determined with any accuracy.



Graph to get number of absorbing atoms
(Area $p_0 b$)

FIG. 4

5. ACCURACY OF THE METHODS ADOPTED

(*i*) *Measurement of absolute f-values.*—Besides the errors to be treated under relative measurements an important error in the measurement of absolute values originates in temperature measurement. An error of two or three degrees in knowing the temperature alters the vapour pressure and so the results by about 10%. The partial pressure of the atoms in the vapour is also uncertain by a factor of about 3%.

The greatest error comes in if we assume the vapour pressure at any point along the axis to correspond to the temperature at that point. With this assumption the calculation of the f-value for the second line was attempted. In the case when foreign gas pressure was about 50 cm. the f-value came out to be 100 times that when the pressure was only 7 mm. The bigger value itself was only one-third the value given by theory (.012). Extremely low values for low foreign gas pressures appear to show that the actual quantity of vapour giving absorption is much less than that assumed on vapour pressure data. Ditchburn, Tunstead and Yates (1942) have studied this problem of dynamic equilibrium of a vapour assuming the foreign gas to remain stationary. Though their results in the form given cannot be applied to the present shape of the tube, yet these amply show that the amount of vapour increases

progressively with foreign gas pressure. These considerations restrict the utility of the method to determination of relative *f*-values only, where a knowledge of the exact amount of absorbing vapour is not needed.

(*ii*) *Errors affecting relative f-values as well.*—Systematic errors which may come up due to progressive changes in intensity of the sources or systematic variations in the developed plates have been reduced to minimum by intermixing at random the absorption and calibration spectra on the plates and by careful developing.

(*a*) *Errors due to variations of sources.*—By adjusting the pressure inside the hydrogen discharge tube to a value slightly higher than that required for least damping, the tube is made self-stabilizing. Changes of current cause compensating changes in pressure. The tube runs with practically no change in intensity unless it has been standing idle for long when it requires about half an hour to come to stable conditions. Fluctuations in the primary current due to supply mains have to be controlled by hand. The ammeter reading fluctuations averaged over the time of exposure do not exceed .25%.

The light of the photometer bulb shows 1% variations. It was lighted from the mains with a stabilizing circuit given by Potter (1934). Accumulators are not used since they are apt to run down which necessitates repetition of photometry of calibration spectra before and after the absorption is studied.

(*b*) *The unevenness of the plate.*—There can be three types of errors, due to grain of the plate, variations due to uneven development and non-uniformity of the sensitive film. These errors are least in fresh fine grain process plates. Any exposures near the edges of the plates are rejected. Under average conditions contribution from such errors may sum up to 2%, but with special care it is reduced to less than 1%.

(*c*) By far the largest errors arise from the photographic intensity measurements. On average a mistake of about 5% here causes the exponent to vary by $\pm.05$ independent of its magnitude. This causes an error of about 3% in bigger absorption coefficients and a greater error in relatively weak absorption. Greater error thus comes in from the nature of graphical methods employed. Lines showing strong absorption give much more reliable figures than those showing weak absorption. An estimate of accuracy was made by repeating a number of times the microphotometry of two lines, one about 10 times stronger than the other. The maximum divergence of the figures for stronger lines was 2% and for weaker 10%. But as any two neighbouring lines are generally of less intensity ratio and are microphotometered for the same setting of the photometer, the error in the ratio is correspondingly less. Thus for large ratios the probable error in all is about 10% and for ratios between lines of small intensity variation the errors vary between 5% and 8%.

6. OBSERVATIONS AND RESULTS

It was expected that better comparison with theory would be possible if low temperature and low foreign gas pressure were employed. In majority of cases the foreign gas pressure was only a few millimeters just to guard against distillation of the metal to cooler portions. Temperatures were between 200°-400° C and effective concentration of vapour corresponded to still lower temperatures on account of rapid diffusion of the metal. In all about 400 exposures were given, out of which 150 were absorption spectra and others intensity and wavelength calibration spectra. About 30 absorption exposures were on infra-red plates and the rest on process plates. The observations are listed below.

(1) On increase of pressure of foreign gas it appears as if a greater amount of vapour begins to absorb; the intensity of lines as well as their number increases (Plate IB), which shows that a larger foreign gas pressure makes the vapour tend to accumulate and build up the vapour pressure corresponding to the temperature at that place. This should also explain similar observations of Bhattacharya and Sinha (1943). Difficulties in calculation of absolute *f*-values arising from this uncertainty in the amount of absorbing vapour has been already dicussed in 5(*a*).

(2) The experimental data for the exposures selected for photometry is given in the first 5 columns of Table I(*a*) and in the rest of the table the areas (G) proportional to *f*-values are given. The areas are also reduced on a scale of *f*-value for the second line as unity (figures in brackets). The table is completed for higher numbers on some of the plates in the part I(*b*). The mean results are tabulated in Table II. The theoretical values (Nanda, 1945) reduced to the same scale are given in brackets. The *f*-ratios are also seen to be affected by the conditions of excitation.

(3) Lines 16 to 24 were not clearly resolved. Due to limited dispersion of the spectrograph, these lines overlap and an apparent continuous absorption before the series limit results (Plate I(*c*). This explanation has been given by Trumpy (1928) in connection with his observations on absorption of sodium vapour. The values of the individual lines have been calculated assuming arbitrary symmetrical distributions in the lines, giving the observed curve as their sum.

(4) Continuous absorption shows a minimum at about 2700 Å. The results are analogous to those of Ditchburn and others (*loc. cit.*) After a weak maximum at the series limit the absorption diminishes and then rises again towards the shorter wavelengths.

(5) Band absorption is very marked. The expected small percentage of molecules present at these temperatures appears to be very effective. Bands on both sides of the atomic series lines were present and the position of these was unaffected by the nature of filling gas. The strength of the band system $C^1\pi \rightleftharpoons A^1\Sigma$(6280 Å – 6925 Å) on the above *f*-value scale is given in the Table I(*a*).

TABLE I(*a*)

No	Filling Gas		Temp. °C			Rel. Absorption in lines etc.				
	Nature	Pressure	A	B	C	1	2	3	4	5
1	N_2	3 mm.	222	228	228	78.5 (16.06)	4.9 (1.0)	(Band 91.8)		
2	N_2	14 mm	222	228	228	142 (9.28)	15.3 (1.0)	(Band 38.4)		
3	A	11 mm.	238	240	237	12.9 (6.45)	2.0 (1.0)			
4	A	11 mm.	266	281	267	38.6 (6.43)	6.0 (1.0)			
5	A	11 mm.	297	314	298	162.0 (13.84)	11.7 (1.0)			
6	N_2	10.8 cm.	163	171	167		3.15 (1.0)	.98 (.311)		
7	N_2	50 cm.	164	171	168		8.83) (1.0)	3.16 (.358)		
8	A	7 mm.	264	282	265		4.64 (1.0)	1.77 (.382)		
9	A	7 mm.	300	314	300		11.4 (1.0)	4.67 (.410)	2.84 (.249)	1.51 (.132)
10	A	9.4 cm.	290	309	302			5.78 (.410)	4.03 (.286)	1.95 (.138)
11	A	7 mm.	358	381	352					
12	A	7 mm.	394	412	381					

TABLE I(*b*)

Line No.	Plate No. 11	Plate No. 12	Line No.	Plate No. 11	Plate No. 12
5	9.10 (.135)		15	.77 (.011)	4.0 (.011)
6	6.77 (.098)		16	.61 (.009)	3.4 (.009)
7	3.98 (.058)		17	.49 (.007)	3.3 (.009)
8	2.38 (.034)	13.0 (.034)	18	.40 (.006)	2.6 (.007)
9	1.73 (.025)	10.4 (.028)	19	.35 (.005)	2.5 (.007)
10	2.07 (.030)	9.8 (.026)	20	.28 (.004)	2.3 0(006)
11	1.95 (.028)	7.9 (.021)	21	.20 (.003)	2.1 (.006)
12	1.38 (.020)	6.3 (.017)	22		1.9 (.005)
13	1.48 (.025)	5.1 (.014)	23		1.7 (.004)
14	0.92 (.013)	4.4 (.012)	24		1.6 (.004)

TABLE II

Line No.	Relative *f*-value	Line No.	Relative *f*-value	Line No.	Relative *f*-value
1	6.4 to 16.1 (91.5)	9	.026	17	.008
2	1.0 (1.0)	10	.028	18	.006
3	.365 (.2 2)	11	.025	19	.006
4	.268 (.263)	12	.018	20	.005
5	.135 (.0006)	13	.018	21	.005
6	.098	14	.012	22	.005
7	.058	15	.011	23	.004
8	.034	16	.009	24	.004

(6) Continuous molecular absorption overlaps the first few members of the principal series. The line strength was calculated by assuming the lines to be imposed on continuous absorption, thus altering the magnitudes of calibration transmissions.

7. DISCUSSION OF RESULTS

The chief points needing careful investigation emerge to be the nature of foreign gas effects on the intensity ratios; and the ratio of the first line to the second line being only between 6.4 and 16.1 whereas the theoretical value as well as that obtained from experiment on anomalous dispersion is about 100.

The ratios have been calculated by the direct method, regrded as applicable since the records show pointed peaks in the centres much below complete absorption range. It would not be out of place to mention that the apparent width of these lines under a high power microscope was for the narrowest lines about four times the width of the microphotometer slit image (12μ). The lines were obtained by a spectrograph slit of width 3μ which covers a range of about .04 Å on the photographic plate in the ultraviolet region and .3 Å in the infra-red region. The lines therefore fairly represent true distributions. The microphotometer slit had a fixed width, but a finer slit would be preferable. Other problems are regarding the great intensity of the bands and anomalous continuous absorption.

In the end I wish to thank Dr. P. K. Kichlu for suggesting the problem and for his continued interest and encouragement during the course of these experiments. I am indebted to Mr. B. M. Anand for discussions bearing on problems connected with photographic photometry. My thanks are also due to Mr. Kundan Lal, M.Sc., and Mr. C. L. Arora, M.Sc., for help in taking some of the absorption photographs.

The author is very much indebted to Prof. M. N. Saha, F.R.S., of the University of Calcutta for allowing the author to use the microphotometer of his laboratory in the earlier stages of the work.

PHYSICS LABORATORY,
GOVERNMENT COLLEGE,
LAHORE.

REFERENCES

Bay and Steiner (1927), *Zeits. f. Phy.*, **45**, 337.
Bhattacharya and Sinha (1943), *Ind. J. Phy.*, **17**, 131.
Ditchburn (1927), *Proc. Camb. Phil. Soc*, **27**, 959.
Ditchburn, Tunstead and Yates (1942), *Proc. Roy. Soc.*, **181**, 386.
King and Stockbarger (1940), *Astrophy. J.*, **91**, 488.
Kistiakowsky (1931), *Rev. Sci. Inst.*, **2**, 549.
Lawrence and Eldefassen (1930), *Rev Sci Inst.*, **1**, 45.
Nanda (1945), *Ind J. Phy.*, **19**, 1.
Petter (1934), *J. Sci. Inst.*, **11**, 95.
Trumpy (1925), *Zeits. f. Phy.*, **34**, 715.
,, (1927), ,, ,, ,, **44**, 575.
,, (1928), ,, ,, ,, **47**, 804.
Weiler (1929), *Ann. Der. Phy.*, **1**, 361.